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Support for solar PV deployment in Spain: Some policy lessons

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ABSTRACT

This paper provides an overview of the trends of the Spanish solar PV feed-in tariff (FIT) and its design elements, identifies some implications for the effective and cost-efficient deployment of solar PV in Spain and infers some lessons which might be useful for the implementation of support for solar PV elsewhere. Our analysis is based on a throughout revision of the relevant legislation, official data on deployment and related expenditure, informal discussions with key stakeholders and written documents. Several key design elements within FITs that should be implemented and other elements that should be avoided in order to have an effective and cost-efficient promotion of solar PV are identified. All in all, the specific design elements to be included are clearly contingent upon the preferences and priorities of policymakers.

Contents

1. Introduction

Several international institutions, like the European Commission and the International Energy Agency, have pointed to Spain as a success story showing how government policies jump-started renewable energy, created new industries, and helped the environment [1,2]. However, it has usually been pointed out that there have also been some shadows in the Spanish experience with the public promotion of solar PV. In particular, although the support instrument used in Spain (feed-in tariffs, FITs) has shown to be the most effective instrument to promote solar PV everywhere (see Section 2), it has led to a boom-and-bust cycle in Spain, with negative consequences for, both, consumers (boom) and investors (bust). Indeed, a current concern in several countries, such as the Czech Republic, Italy, France and Germany, is how to balance increasing penetration rates for solar PV with the control of consumer costs [3–6]. Although this concern is greater at a time of economic crisis and austerity as that experienced by many European countries, it is not restricted to developed countries.

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According to [7], sensitivity to policy costs is even more significant in developing country markets and a common approach to renewable energy promotion in developing countries has been to "rationalize development and deployment strategy".

Both lights and shadows of this policy provide useful lessons for the public promotion of solar PV. Countries engaging in solar PV support should learn from the Spanish experience and not incur the same mistakes.

The first aim of this paper is to provide an overview of the trends in solar PV policies (design elements of the feed-in tariff, FIT) in Spain. The second one is to identify some implications for the effective and cost-efficient deployment of solar PV in Spain. The last goal is to infer some lessons which might be useful for the implementation of low-carbon deployment regulation (and specifically, solar PV support) in other countries. This paper focuses on the "cost" side of the public promotion of solar PV deployment, since this has been the major concern in those countries undergoing a significant increase in solar deployment such as Spain, Italy, the Czech Republic, Germany and France. But, of course, solar PV deployment brings several social benefits, including reductions in fossil fuel imports, CO2 emissions and employment creation (see [36]) for a discussion of these benefits in the Spanish context). In addition, while the cost side of public support is highlighted in this paper, support schemes for investments in R&D and deployment are required in order to achieve costs reductions in the technology and make solar PV competitive. Cost-containment and cost-reductions are to main aspects of public support for solar PV.

Our overview and analysis is based on a throughout revision of the relevant literature. We have undertaken an in-depth examination of the evolution of the contents of regulations relevant for solar PV promotion in Spain between 1998 and 2011, including drafts of finally implemented regulation. This was complemented with official data on deployment and related expenditures, informal discussions with key stakeholders and written documents (including statements made by RES-E generators, reports issued by the National Energy Commission –CNE-, and declarations made by policy makers published in the general and business press).

Accordingly, the paper is structured as follows. The next section provides a brief overview of the literature on the support for renewable energy technologies in general and solar PV in particular. Section 3 outlines the trends of solar PV regulation in Spain (including major design elements) and their implications in capacity additions and support costs. Section 4 discusses the main lessons that can be inferred from the evolution of policies and design elements. Section 5 concludes.

2. Instruments for the support of solar PV around the world

Several instruments to support the diffusion of renewable energy technologies in general and solar PV in particular have been implemented around the world, including feed-in tariffs (FITs), quotas with tradable green certificates (TGCs), bidding/tendering schemes, low-interest loans, investment subsidies, net metering and fiscal incentives [3,8–11].

FITs are the most popular support policy, followed by quotas with TGCs. Investment subsidies have also shown to be very relevant for solar PV deployment. FITs are preferential prices to renewable energy generators per kWh generated, combined with a purchase obligation by the utilities. Quotas with TGCs are certificates issued for every MWh of renewable electricity. They allow generators to obtain additional revenue to the sale of electricity. Demand for TGCs originates from an obligation on electricity distributors to surrender a number of TGCs as a share of their annual consumption (quota). Otherwise, they should pay a penalty.

These instruments are not used to the same extent around the world. FITs are predominant in this context. They are in place in 61 in countries and 26 states/provinces worldwide. Quota policies (not necessarily combined with TGCs) are implemented in 10 countries and in at least 50 other jurisdictions [7]. Investment subsidies are granted per kW of capacity, not production and, as FITs, their use is widespread, usually, but not always, coexisting with the other two policies [11].

The empirical literature on renewable energy instruments, mostly restricted to case studies, has generally focused on the impact of different instruments on electricity generation capacity and static efficiency, both for EU countries, the US, Japan and Australia [2,12–15]. This literature shows that FITs generally perform better than TGCs regarding effectiveness and static-efficiency [1,2,9], mostly due to the lower risks for investors under FITs [16]. In contrast, under TGC schemes, uncertain and volatile TGC prices involve a risk premium which increases financing costs and discourages investments.

Quotas with TGCs have proven to be particularly problematic to encourage a substantial increase in solar PV deployment. This is so because, under TGCs, the cheapest technologies are privileged over expensive ones, including solar. This has been shown to be the case in the U.K. [17], Sweden [18], Flanders [19], Japan [14], Australia [15], Texas and California [20] (the evidence in other US states is mixed [13]).

This paper focuses on FITs, since this instrument has proven to be more effective than other instruments in supporting solar PV. In the EU, nearly 100% of the new PV capacity since 1997 was installed in countries using FITs [21] and nearly all countries with growing PV markets have used FITs [22]. In addition, FITs is the instrument applied in Spain, the subject of this case study.

While comparative analysis of instruments has focused on two criteria (effectiveness and cost-effectiveness), and the literature has shown that FITs are both more effective and efficient (in terms of € of support per MWh of generation) [1,2,22], the increasing support costs of solar PV in some countries using FITs (Germany, Spain, Czech Republic, France and Italy) has added a new criteria: the total policy costs of the scheme and how to combine increasing deployment levels with decreasing total policy costs. This represents a challenge for policy makers which should be tackled with specific design elements, as this paper argues with respect to solar PV promotion in Spain.

Indeed, it has been found out elsewhere that the success of support schemes depends as much on the instrument chosen as on their design elements [1,9]. In other words, the success may be more related to intra-instrument (design elements) choice than to inter-instrument choice. There are several relevant design elements of FITs. Table 1 describes the most relevant design elements of FITs, whereas Table 2 provides information on where they have been implemented in the EU. It can be observed that some design elements are highly common, others are less common and yet some are highly uncommon.

Finally, several papers have paid attention to the Spanish case. [23] analyses the political economy of successive renewable energy regulations in Spain but only until 2007 and without a specific focus on the case of solar PV. Similarly, [24] include Spain in their comparative assessment of solar PV regulations in the Mediterranean countries, although the analysis stops in 2008, which is precisely the date at which the 2008 regulation (Royal Decree 1578/2008) was approved, creating a boom-and-bust cycle. Thus, reasons for this cycle are not provided and policy lessons are not derived. References [10] and [25] also include a comparative analysis of the Spanish case and other countries.

Table 1
Main design elements of FITs.

	Description
Fixed-premium versus fixed-tariff	Tariff: a total amount of support is granted to RES-E generators per kWh. Premium: an additional amount to the electricity price is granted
Technology-specific FITs vs. flat support levels for all technologies	Support is differentiated across technologies to reflect technology-specific generation costs
Support tied to electricity price	Support may or may not be linked to the electricity price
Support paid by electricity consumers vs. paid by taxpayers	Support can be charged to consumers or taxpayers
Degression.	Reductions over time in support levels for new plants. Degression rates: % reduction of support per year
Cap price	Support is capped (electricity price + premium)
Floor price	A floor ensures a minimum support level (electricity price + premium)
Maximum size of plants.	Only installations below a certain capacity threshold would receive the support
Capacity limit per technology.	Cap on technology deployment eligible for support (overall or for individual technologies)
Duration of support	Support may be guaranteed for a longer or shorter time
Cost-containment mechanisms	Some elements may help to control costs: limits on generation eligible for support, capacity limits, cap on total costs…
Reduction of support for existing plants	Reductions of support over time for existing plants, compared to providing the same overall amount of support for the whole period, but constantly over time

Source: Own elaboration.

However, those papers do not provide a detailed analysis of solar PV regulation and the situation post-2008 is not analysed.

3. A dynamic perspective on the choice of design elements for the solar PV FIT in Spain

3.1. The boom: The pre-2007 regulations

Since 1998, under Royal Decree (RD) 2818/1998, solar PV has been promoted in Spain mainly with a FIT, adjusted in 2004 (under RD436/2004) and 2007 (RD661/2007)[2] . Deployment of solar PV only started to rise significantly since 2006 under RD 436/2004. The previous FIT of 1998 did not have a significant effect on RES-E deployment, mostly due to the relatively low support levels (see Figs. 1 and 2) and the uncertainty for investors related to the annual updating of support. Moreover, despite the fact that net-metering was apparently encouraged (indeed an attractive FIT for installations less than 5 kW was established), specific administrative rules to promote it were never set up. The draft of the Royal Decree Law regulating self-consumption is expected to be approved in May 2012. Under RD 436/2004, in addition to other features existing in previous regulation (the RES-E purchase obligation for the utilities and the double option for RES-E generators for either a premium on top of the electricity price or a tariff for the whole amount of RES-E fed into the grid), support levels were set as a percentage of the electricity price, with revisions every four years.

Although before 2007 the priority was to provide a sufficient boost to the deployment of solar electricity, apparently regardless of costs[3], the real boom of solar PV in Spain took place under the new 2007 FIT (i.e., after RD661/2007 was in force). Since solar deployment was relatively behind the Renewable Energy Plan (2005–2010) targets (400 MW for 2010), the aim of the new Royal Decree was to accelerate solar deployment in order to comply with those targets.

As it is shown in Fig. 2, from April 2007 to August 2008 the expansion rate of solar PV deployment was astonishingly fast. In 2008, 2708 MW of PV capacity were added, up from 544 MW in 2007. However, if Figs. 1 and 2 are compared, it would not be wholly wise to attribute the 2007–2008 solar boom to the 2007 FIT. Contrary to what it is usually believed [6,24] support levels did not increase significantly (with the exception of PV installations with capacity >100 kW and ≤ 10 MW) with respect to the 2004 FIT, although the lower risks (since support levels were no longer tied to electricity prices as in RD 436/2004) made the 2007 FIT more attractive for investors. Official data from the National Energy Commission ([37]) shows that capacity installed increased by about 2700 MW between 2007 and 2008. Of this increase, 80% (2153 MW) was due to the increase in capacity deployed by installations with capacity lower than 100 kW, although most of these plants were *huertos solares* (literally "solar orchards"), that is, large PV plants gathering together installations just below 100 kW, each with its owner. The rest (20%, or 550 MW) took place in the segment from 100 kW to 10 MW, which is precisely the one which experienced the largest increase in remuneration (from 0.23 to 0.42 €/MWh). Thus, if support levels had been the exclusive cause for the boom, this boom should have started in 2006 or even before, not in 2008. Therefore, several other factors account for the explosive growth of solar PV in 2008:

1. The stagnancy of the housing market which had been benefiting from a long wave of striking growth. Construction companies had accumulated a large surplus as a result of the housing boom in previous years. They were looking for profitable investment alternatives. Solar PV investment became an interesting financial product because of high internal rates of return coupled with very small risks.
2. In turn, access to credit was relatively easy and low interest rates facilitated the financing of projects by smaller investors. In this latter case, the project finance scheme became routine.
3. Acknowledging the local socioeconomic benefits of solar PV deployment, regional and local governments (responsible for the granting of different administrative permits) were eager to grant those permits without delays.
4. Most importantly, article 22 of RD661/2007 stated that, once 85% of the PV target (371 MW) was reached (which occurred on the following month of June), a new royal decree should be approved in a period not less than one year. Although support levels for installations deployed after that date were unknown,

[2] This is not the place to discuss the history of the FIT in Spain in detail, but just to highlight the most relevant regulations and design features affecting solar PV deployment. For an overview of FITs in Spain, see [23,33].

[3] For example, when assessing a draft of the new FIT in 2007, the National Energy Commission claimed that only four criteria were relevant in this regard [25]: effectiveness (achieving the renewable electricity targets), minimizing regulatory uncertainty, facilitating the operation of the electricity system and encouraging the participation of renewable electricity in the electricity market). There is no mention to costs in this 116-page report.

Table 2
Implementation of design elements in EU countries.

Country	Tariff/ Premium	Techno-specific support	Link to elect. price	Costs to consumers?*	Degression	Cap/ Floor	Max. plant size**	Capacity cap	Duration	Cost-containment	Reduction for existing plants
Bulgaria	Tariff	Yes	Yes	Yes	Not	Not	Not	Not	15–25	Not	Not
Denmark	Premium	Yes	Not	Yes	Not	Yes (cap)	Not	Not	20	Not	Yes (premium is reduced after 10 years)
Germany	Tariff	Yes	Not	Yes	Yes (flexible)	Not	Not	Not	15–20	Registry	Not
Estonia	Tariff and Premium	Not	Not	Yes	Not	Not	100 MW	Not	12	Cap on generation eligible for support	Not
Finland	Tariff	Only elect. from peat eligible	Not	Yes	Not	Not	Not	Not	-	Maximum annual amount of support	Not
France	Tariff	Yes	Not	Yes	Yes	Not	12 MW, Solar: 3 kWp	N (annual cap only for solar)	15–20	Eligibility for PV support suspended	Not
Greece	Tariff	Yes	Not	Yes	Yes	Not	Not	Not	20–25	20–25	Not
Ireland	Premium	Yes	Not	Yes	Not	Not	Not	Not	15	Not	
Italy	Tariff	Yes	Not	Yes	Not	Not	1 MW (0.2 MW for wind)	Not	15	Not	Not
Latvia	Tariff	Yes	Not (link to gas prices)	Yes	Not	Not	Not (max. generation hours eligible).	Not	20	Cap on generation eligible for support	Yes (tariff decreases after 10 years for non-solar)
Lithuania	Tariff	Yes	Not	Yes	Not	Not	Not (max. generation hours eligible).	Not	Lifetime of plant	Not	Not
Luxembourg	Tariff	Yes	Not	Yes	Yes	Not	Biomass: 5 MW, solar: 1 MWp…	Not	15	Not	Not
Malta	Tariff	Only solar PV eligible	Not	Yes	Not	Not	Not	Not	Lifetime	Not	Not
Netherlands	Premium	Yes	Not	Not (taxpayers)	Not	Not	Not	Not	15 (12, biomass)	Total amount of subsidy (first-come-first-served)	Not
Austria	Tariff	Yes	Not	Yes	Yes	Not	Not	Not	13 (15, biomass)	Total amount of subsidy (first-come-first-served)	Not
Portugal	Tariff	Yes	Not	Yes	Not	Not	Yes (except wind)	Not	12–25	Not	Not
Slovakia	Tariff	Yes	Not	Yes	Yes (unless project is co-funded by the government)	Not	Yes	Not	15	Not	Not
Slovenia	Tariff and Premium	Yes	Not	Yes	Yes (only for PV)	Not	5 MW (tariff); 125 MW (premium)	Not	15	Not	Not
Spain	Tariff and Premium	Yes	Not	Yes	Not (improper degression for PV).	Yes	Yes	Yes (solar PV, other: revisions when targets are met)	20–28	(*cupo* system, see text)	Yes (support is reduced after 20 years)
Czech R.	Tariff and Premium	Yes	Not	Yes	Not (very simple)	Not	Wind: 20 MW; solar: 30 kW	Not	20–30	Not	Not
Hungary	Tariff	Yes (limited disaggregation)	Not	Yes	Not	Not	Not	Not	Pay-off period	Not	Not
Cyprus	Premium	Yes	Not	Yes (tax on elect.)	Not	Not	Not	Not	Lifetime	Not	Not

Source: Own elaboration.

investors expected them to be lower. Indeed, a draft of the new Royal Decree in September 2007 was made public and showed a substantial reduction in support levels compared to the existing Royal Decree. This created a rush to submit proposals for the existing FIT during the spring and summer of 2008. On September 28th 2008 a new regulation entered into force (RD1578/2008). At this moment, solar PV capacity had reached 3116 MW, when capacity at the end of 2007 was 695 MW.

5. The modular and easy-to-install features of solar PV facilitated its fast deployment, especially regarding the smaller plants.

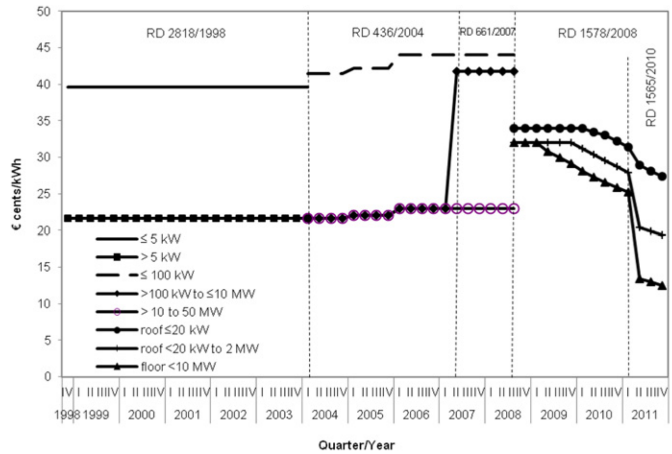


Fig. 1. Regulated tariff for solar PV (€ cents/kWh).
Source: Own elaboration.

The impact of this technical feature was encouraged (from 1998) by the option of the *huertos solares* which could simultaneously take advantage of the highest FIT and economies of scale. Therefore, the number of potential (and actual) investors was very large.

6. The $/€ exchange rate increased since 2006 until 2008. From June 2007 to August 2008 the average exchange rate was 1,47 $/€. The stronger euro fostered imports of PV cells and modules: in 2008, solar PV imports totalled 5182.5 M€ (55% from China)[26,32]. This figure represents around 1700 MW (~60% of total installed capacity).
7. Despite the fact that the costs of modules slowly decreased since 2007 until early 2009, Spanish prices remained high. But this had only a limited impact on the profitability of investments[4].

The exponential growth in solar PV deployment triggered a parallel exponential growth in the total costs of solar PV support and raised the concern of the government. Table 3 shows the evolution of PV total promotion costs and energy feed-in with respect the RES-E and the electricity generation mix from 2004 to 2011. As it can be seen, the PV source has been a small share of RES-E and, simultaneously, an important portion of the total cost of RES-E promotion.

Compared to other countries, the specific support for solar PV in Spain is large regarding support per MW, but is not concerning support per MW h. According to the International Energy Agency [22], in 2008/2009, the average "remuneration adequacy indicator (RAI)" which provides remuneration levels across countries, correcting for the country's different resource endowments was $762,514/MW in Spain, higher than in any other OECD country except Italy. Average normalised remuneration per MW h amounted to $522/MW h in Spain which was lower than in other EU countries (Czech Republic, Belgium, Germany, Italy, Portugal, France, Greece, the Netherlands and the Slovak Republic), although higher than in the Nordic countries, Austria, Hungary, U.K., Ireland and Poland.

From 2009 ahead, the debate about the PV financial burden has been blended with the question of the tariff deficit of the Spanish electricity system. Despite the fact that they have very different character, both were mixed in the upsetting question of controlling the rise of the electricity bills. From the end of the later century the successive governments have decided to maintain electricity regulated tariffs in a very affordable level. Unfortunately, from 2006 onwards, the tariffs proceeds became in short regarding the outlays of the electricity system, amongst them premiums to the RES-E. This fact has given rise to a huge accumulation of tariff deficit (more than 24,000 M€ at the end of 2011) which is considered as a customer debt vis-à-vis the electricity sector. This deficit has been gradually securitized and placed in the international financial markets at 6% interest rate and 15 years of amortization period.

3.2. The bust. The post-2008 regulations

Given the aforementioned concern about policy costs, both ordered capacity growth and cost-containment became priorities in the new regulation, i.e., RD 1578/2008, which regulates the economic regime of solar PV plants installed after 9/28/2008. Two main features of this royal decree should be highlighted:

1. A capacity quota (*cupo*) system for each type and subtype of installation was adopted. This gave rise to the creation of the Registry for the pre-allocation of support, in which all the PV installations should be inscribed following a sequential order to meet the allowed additional capacity.
2. The RD classified installations into type I (roofs/facades) and the rest. In turn, type I installations are further classified according to their size into subtype I.1 (< 20 kW) and subtype I.2 (> 20 kW but less than 2 MW). For the first call, the regulated tariffs were 34 cent€/kWh for subtype I.1 installations and 32 €cents/kWh for subtype I.2 and type II installations.

First year (2009) calls had the following associated capacity targets: 267 MW/year for roofs (10% for type I.1 and 90% for type I.2) and 133 MW/year for floors (divided by four quarters). Additional capacity targets for floor installations were temporally included: 100 MW in 2009 and 60 MW in 2010. Thus, the targets for 2009 and 2010 were 500 MW each year.

Capacity is allocated on a first-come-first-served basis. There are four calls (and quotas) during the year:

1. If less than 75% of the quota ($\bar{q}$) is met, then the pre-established FIT level is maintained for the next call. That is, if $q_{k-1} \leq 0.75\bar{q}_{k-1}$ tariffs do not change, i.e., $p_k = p_{k-1}$, where k stands for "quarter".
2. If more than 75% of the quota is met, then the FIT level is proportionally reduced (0% reduction with 75% and 2.6% reduction with 100%). That is, if

   $q_{k-1} > 0.75\bar{q}_{k-1}$

   then,

   $$p_k = p_{k-1} \cdot \left[\frac{(1-0.9^{1/4})(\bar{q}_{k-1} - q_{k-1})}{0.25\bar{q}_{k-1}} + (0.9)^{1/4} \right]$$

   As it is observed, tariff diminishes at a 10% inter-annual rate.

Moreover, capacity for the annual call (V_n) and the change in the tariff in the previous year (p_{n-1}) move in opposite directions, that is,

$$\Delta V_n = V_{n-1}\ \Delta p_{n-1}$$

In other words, under this *cupo* (dynamic quota) system, capacity growth and support levels were set in a circular way over time. Targets for the 2nd and following years would increase or decrease (with respect to the targets for the first year)

[4] In the economic impact assessment of the RD661, an internal rate of return from 5% to 9% was considered. However, internal rates of return (IRRs) of between 10 to 15% and more have been common. This was also due to a greater number of high-quality radiation hours than expected.

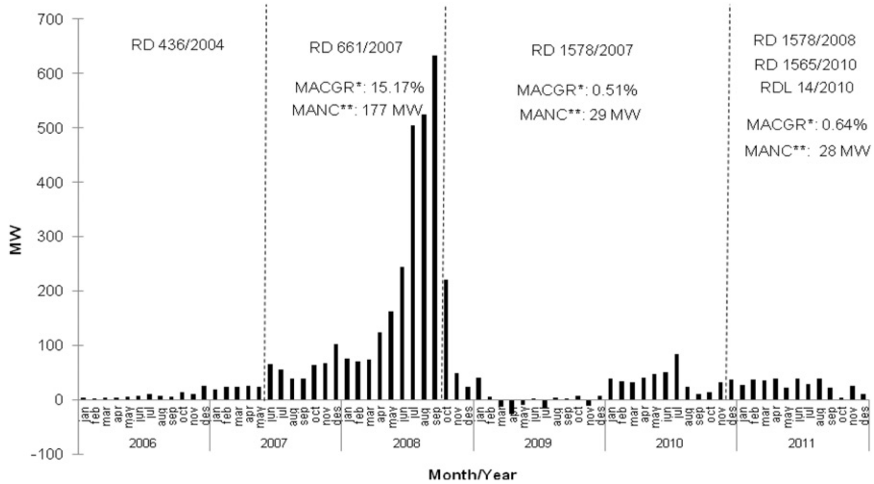


Fig. 2. Monthly additional capacity in solar PV. *Monthly Average Compound Growth Rate, **Monthly Average New Capacity, Negative values stem from data base corrections. *Source*: Own elaboration from CNE (several years)

Table 3
Evolution of PV tariffs and generation.

Year	Total tariffs paid to the PV generation (thousand euro)	Average tariff cost of MWh PV (euro)	% PV tariffs with respect all renewable[a] tariffs	% MWh PV into the renewable[a] generation mix	% MWh PV into the global generation mix
2004	6,146	341.44	0.93	0.08	0.01
2005	13,995	341.34	1.75	0.15	0.01
2006	39,887	372.78	3.53	0.35	0.04
2007	194,162	392.25	13.44	1.36	0.16
2008	989,248	388.39	40.86	5.81	0.83
2009	2,607,931	429.86	56.48	11.40	2.17
2010	2,650,897	414.27	49.61	10.04	2.15
2011	2,387,303	324.58	47.84	12.46	2.79

Source: Own elaboration from CNE [27] (several years).

[a] Renewable sources: Hydroelectric power, wind power, biomass power, CSP and PV.

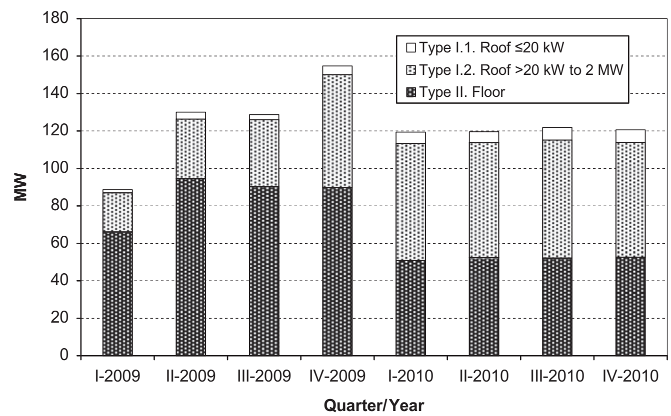


Fig. 3. Evolution of registered capacity under RD 1578/2008.
Source: Own elaboration from official data by IDAE (Instituto para la Diversificación y el Ahorro de la Energía).

according to the reduction or increase in the tariff levels in the previous year which, in turn, depend on the evolution of capacity in the previous year with respect to quarterly targets.

Within RD 1578/2008 a rule for transferring quota between the calls was foreseen. In addition, this royal decree had other design features: there was a requirement for a guarantee obligation (500 €/kW) for those registering in the *cupo* system in order to avoid speculation in trading deployment rights. The duration of support was set in 25 years and support was adjusted for inflation over time (minus some basis points as an incentive for efficiency improvement).

As expected, new capacity additions after the passing of RD 1578/2008 stagnated. Although 502 MW were accepted, only 155 MW (official data [27]) were actually installed in 2009. Moreover, the delay in the publication of the first call for the first quarter of 2009 literally paralyzed the Spanish market for several months (October 2008–March 2009). In addition, lack of experience with the administrative procedures in the new FIT may have discouraged new capacity additions. Finally, the economic crisis and the difficult access to credit also played a role. Indeed, the Association of the Solar Industry (ASIF, in Spanish) argues that this later factor has been the main barrier to solar PV deployment in the short and medium terms [28].

Another problem was the huge number of PV projects still in-progress when the regulation changed: in 2009, applications for ground installations were high above annual targets (4400 MW vs. 500 MW).

Note that, contrary to the indicative targets (caps) in the German system, the Spanish cap is a quota, i.e., a mandatory cap that cannot be exceeded since capacity exceeding the cap is not eligible for the FIT. In contrast, in 2009 the target for building (roof) installations was not covered (due to the inexperience in installing them and administrative hurdles). In 2010, the target was finally met for building installations. See Fig. 3 which is referred to the registered capacity, that is, projects accepted to be included in the quota of a given quarterly call of the Registry for the pre-allocation, but not yet built and operating.

The Spanish regulatory framework for solar PV, including RD1578/2008, has only encompassed commercial installations (all sizes comprised). In 2006, 21% of new capacity installed in that year (32 MW) was from installations below 5 kW. In 2007 this share went down to 6.5% (45 MW) and in 2008 it was even lower (1.7%, 58 MW). Compared to Germany, the share of small installations is much lower. In Spain only 5% of the installations are small roof-top plants below 20 kW, but practically all of them commercial. In Germany, the newly installed power of plants below 30 kW in 2009 was approximately 40% of the total. A survey of administrative barriers for solar PV deployment in several EU countries shows that, in Spain, these hurdles for the

residential sector (i.e., small installations of 3 kW) are significantly higher compared to other countries. Indeed, on the one hand, administrative procedures has been lengthy than adequate and the pre-registration (a very long and bureaucratic process on which the eligibility of every PV project depends on) has had an important impact on PV deployment (see [35]). On the other hand, specific measures for promoting net metering have not been implemented in Spain. The project procedure has almost been identical for the residential, commercial rooftop and ground-mounted systems [35].

In spite of the reductions of support levels over time (see Fig. 1), the total costs of PV promotion have increased, as mentioned above. Thus, the successive governments have struggled to contain the increasing total costs of support and, hence, energy bills. This led to several new regulations, which partially amended either RD661/2007 (for PV plants installed before September 2008) and/or RD1578/2008 (for plants installed after that date)[5]:

1. According to RD 1565/2010, the duration of support for plants under RD661/2007 is capped at 25 years (instead of lifetime), although it has been later increased to 28 years in RDL 14/2010. Since under RD 661/2007 support was granted for the whole lifetime of the plant, the 28 years duration has been considered retroactive by the sector. Plants under RD 1578/2008 have their support capped to 25 years.
2. According to RD 1565/2010, new PV plants which register for the first call after November 23rd 2010 have their support momentarily reduced by 5% (type I.1 installations), 25% (type I.2 installations) and 45% (ground installations).
3. A generation cap is implemented in RDL 14/2010 which limits the number of hours eligible for the tariff for plants under both RD 661/2007 and RD 1578/2008. The number of annual hours eligible for support varies between 1250 and 1707 for installations under RD 661/2007 (until 31st December 2013) and between 1232 and 2367 for installations under RD 1578/2008, depending on the type of installation (fixed installations or tracking installations with one or two-axes) and the solar radiation of the area where the PV plant is installed. This measure has also been considered retroactive by the Spanish solar PV associations (ASIF, APPA, AEF and Anper). With this, the government plans to save consumers 740 M€ in 2011, 2012 and 2013.
4. Finally, in January 27th the new government has approved the RDL 1/2012. Appealing to the need to curb the accumulation of the tariff deficit, this norm put off for an indefinite period the Registry for the pre-allocation of new projects and abolishes all types of RES-E preferential tariffs and premiums. This norm also stipulates that PV calls of 2012 are suspended. As a result of this moratorium, the future of PV generation in Spain is compromised. However, in some Spanish regions, PV generation is close to the grid parity and, if future regulations promote net-metering, the PV sector will rise again. Moreover, the government is convinced that to stop off RES-E promotion will not hinder to achieve the 2020 targets for both renewable energy and greenhouse-gas emissions.

4. Main lessons and recommendations for solar PV deployment

Six lessons can be inferred from the Spanish promotion in promoting solar PV with a FIT. Namely:

[5] Note that, although any new PV plant is subject to RD1578/2008, about 80% of all PV plants currently installed in Spain fall under RD661/2007.

4.1. Introduce cost-containment mechanisms within FITs

The combination of quantity and price (support level) controls may be appropriate for expensive technologies with large potential for technical improvements and cost reductions, such as solar PV, whose deployment may boom unexpectedly. Cost-containment mechanisms would then mitigate the problem that a deployment boom leads to an excessive increase in consumer costs. Several cost-containment mechanisms exist (capacity caps, revisions, flexible degression, caps on total costs, limits on the amount of generation which is eligible for the FIT and so on). All have their pros and their cons, however. Some of them have been implemented in Spain:

a. Total capacity limits per technology (or quotas) directly affect the effectiveness in deployment, especially with low caps. Obviously, this mechanism reduces deployment and limits the increase in consumer costs. On the one hand, this design element would reduce the potential benefits from learning effects if it was implemented world-wide. On the other hand, the cap can encourage the more efficient use of technologies (better placements) in order to get more MW h per MW of installed capacity, since the later is constrained. This may trigger competition to increase revenues, rather than to cut costs. Unfortunately, if the investments returns are higher, this can give rise to a speculation cycle regarding the exchange of the relatively scarce rights of installation.
b. Scheduled revisions involve some adjustments of support levels for new installations. They might be particularly useful to adjust the level of support to the costs for those technologies with very dynamic cost trends, like solar PV. However, frequent, annual revisions (as occurred in Spain until 2004) could undermine investor certainty.
c. Under caps on total costs, a total amount of support is available and granted according to a first-come-first-served criteria, or through auction which transforms the FIT scheme into a tendering/bidding one. It could be particularly suitable for expensive technologies for which a small increase in deployment results in a large increase of support costs. At the same time, it may encourage the low-cost solar PV generators (if support is distributed through an auction). However, again, it would have the same disadvantages as putting a cap on capacity.
d. Limiting the amount of generation eligible for the FIT has recently been implemented in Spain for existing solar PV plants under RDL 14/2010. However, putting a cap on generation discourages the efficient functioning of existing plants (i.e., MW h of generation/MW of capacity) and, to some extent, the manufacturing of more efficient technologies by equipment producers.
e. A particularly attractive cost-containment mechanism is flexible degression. Traditional or "fixed" degression was first introduced in the German EEG in 2000 and refers to previously set percentage reductions over time in support levels (tariffs) for new plants. Although it provides an incentive for technological innovation and cost reductions, it can not accurately correct for sharp declines or extraordinary increases in PV costs. There are two main alternatives to traditional degression: to establish growth corridors, as in the German FIT, or to link support levels and capacity additions in a circular manner. The first option is a modality of degression where reductions in support levels have a fixed part and a variable part which depends on the capacity installed in the previous year. In 2010, the German PV adjustment schedule was set up such that the rate decreased by an additional 1% for each 1 GW above

3.5 GW installed in 2011 [29]. While in Germany the projected annual capacity determines the rate adjustment, in the Spanish case this rate of adjustment takes place quarterly. This kind of very flexible degression was adopted in Spain under RD 1578/2008 (see Section 2.2).

The main advantage of flexible degression is that it controls the overall costs of solar PV promotion due to the interactions between capacity caps and reductions in support levels. The evolution of support levels depends on the reaction of the market to the previous support level. This mitigates the asymmetric information problem that has been common in the past, since the information on technology costs mostly comes from generators, who have an incentive to overestimate those costs [26]. In contrast, this mechanism allows the market to reveal the true costs of the technology. In addition, technological innovation is fostered in so far as reduced support levels induce greater competition to reduce technology costs. These technological innovations and subsequent cost reductions are later enjoyed by consumers. Indeed, under this design element, support costs go down.

However, an important disadvantage of this sophisticated form of degression is the uncertainty for investors (willing to invest in the future) it introduces because they do not know precisely what their revenue flows will be. Indeed, the level of support that will be in force in the future changes very often because it depends on the quarterly evolution of capacity. And, to worsen things, the amount of new capacity to be added has been set at very low levels.[6] On the contrary, the German scheme balances the advantages and disadvantages of traditional degression and flexible degression. It is more responsive to the evolution of the costs of the technology than fixed degression but it provides more certainty than flexible degression on the revenues investors can expect to receive in the future. In short, while the FIT in Germany is mostly a price-based instrument, the Spanish scheme is a hybrid quantity-based and price-based system.

Therefore, the attractiveness of flexible degression for policy makers is contingent upon their political priorities. If cost-containment is their main goal, then flexible degression should be favoured. But if it is an acceleration of deployment levels, then it should probably not. There seems to be a trade-off between the control of support costs and preserving investment stability. The higher the frequency of adjustments (e.g., once in three months as in Spain instead of every two years as in Germany) and the higher the increase of tariff degression in case of overshoot, the higher the control of support costs, but the lower the investment stability. It is probably a valuable design element after undergoing an initial stage of significant market growth.

Finally, net metering (or self consumption) may reduce the policy costs significantly, since if excess energy is not eligible for support, self-consumption comes at zero costs for the consumers. Furthermore, net metering reduces power flows in the distribution network, which reduces losses, improves lifetime of network and postpones grid extensions. In addition, it gives a strong incentive to match generation with consumption, which reduces losses in the distribution network (we thank an anonymous reviewer for these remarks).

[6] In fact, many stakeholders, including the governments of several regions and the Spanish Ministry of the Environment itself, have claimed that the targets are too low (with respect to the submissions). They consider that the caps should be indicative targets as in Germany, but not hard caps that "create uncertainty and juridical insecurity". Therefore, the main problem in establishing caps, an inherent component of a flexible degression scheme, is to set the "appropriate" amount of capacity. An overview of stakeholder opinions on the cupo system can be found in CNE [30].

4.2. Avoid retroactivity

Retroactive regulations changes should be understood as adjustments which negatively affect revenue certainty of operating plants. Of course, there is no such a case if changes in support levels only affect new installations. Once a generator locks into a given rate, the policy should not be *backwardly* and *arbitrarily* readjusted to amend the economic conditions. Both terms refer to a regulatory change modifying the established tariff scheme, which implies a new estimation of the revenues previously gained, probably reducing them, and urging the return of surpluses. In this case there is no doubt: this modification is not acceptable because it is retroactive. However, there is another situation: rates are changed but only with forward effects and provided that the profitability of the investment (internal rate of return) remains unchanged. This kind of regulatory amendment has been accepted by the Spanish Constitutional Tribunal as well as the Supreme Court. They have states that the principle of juridical security cannot be an obstacle to "regulatory innovation". A point of view shared by the regulator (CNE, Comisión Nacional de la Energía) [34]. Put in other words, changes affecting operating plants are admitted but cannot be economically arbitrary, although this later concept is inevitably ambiguous.

From a policy perspective, these legal modifications mean that the benefits in terms of lower support costs in the short term can be more than offset by the negative effects on investor confidence and security in the short and medium terms. For example, the changes induced by RD 1565/2010 and RDL 14/2010 will result in savings of 607 M€ in the 2011–2013 timeframe, a very small fraction of the total costs of solar PV. In contrast, investor's confidence will be seriously undermined. As a general rule, changes to the policy framework over time should be gradual and predictable.

4.3. Try to prevent overheating of the market and capacity booms. In this sense, announcing long in advance the end of the old regulation by a certain date and its replacement by a less attractive scheme could encourage a tremendous rush for the existing, more attractive regulation

One of the reasons of the Spanish boom was the 85% threshold for the PV target which, once reached, would lead to a new royal decree more than one year after (see Section 2.1). Investors rushed to have their installations approved before September 2008 in order to receive the support level of RD 661/2007 because the new FIT was expected to be lower. Other factors facilitated this rush, including the techno-economic features of solar PV (which can be modular and installed very easily and fast), easy access to credit and the investors' pressure on administrative bodies to streamline the granting of the administrative permits.

As a result, the market was overheated. Although it is very difficult to avoid occasional overheating of the market, to establish a long transition period is a very bad regulation design. It was not the threshold by itself but the lack of an accurate plan for the transition period, that is, the extra-time running from the existing regulation (RD 661/2007) to the new one (RD 1578/2008), what was the Achilles" Heel of the Spanish regulation. This prompted the aforementioned enormous increase in capacity and a huge rise in total policy costs. This problem could have been mitigated if the transition period between regulations had been shortened and/or specific measures, probably a mix of quotas and decreasing tariffs, had been established.

4.4. Support repowering in an appropriate manner

Repowering refers to existing PV modules being replaced by new, more efficient ones, increasing the installed power (kWp), without elevating the nominal power of the plant (which is defined by the transformer at the feed-in point). Repowering brings certain advantages compared to green-field projects: new places are not occupied (circumventing the problem of competition for land) and older plants are upgraded and substituted by new ones with better technologies. It is arguable whether or not repowering should be publicly supported [31]. But if it is so decided, then the Spanish case illustrates how this should not be done. Currently, a solar PV module replacing an existing one would receive the same amount of support as the one being replaced, i.e., the higher support level provided by the previous RD 661/2007. But new modules have better production efficiencies than existing ones. According to CNE, the average number of annual hours per installation have increased from 1272 in 2000 to 1547 in 2006 and 1752 in 2010 (whereas the number of hours used to calculate the support under RD 661/2007 were barely 1378), both as a result of technological changes and a greater number of high-quality radiation hours than expected. It has been very profitable for operators to re-power their plants. Therefore, the reasonable recommendation is to give the new PV modules the current lower FIT (not the old, higher one). If the new government is willing to promote repowering, then it should provide a (small) repowering incentive in addition to the new FIT, but the overall level of support for repowered projects should always be lower than the previous FIT.

4.5. Binding targets are not intrinsically better or worse than indicative targets. Long-term targets provide visions which favour investments

Targets in general (whether indicative or binding) provide visions/signals for investors and are instrumental in guiding industry toward making appropriate capital allocation decisions. The adoption of binding targets depends on government priorities: cost-containment or effectiveness in deployment. While Spain has adopted binding targets, worried about the costs of support, Germany has indicative targets, i.e., the targets can be exceeded. Binding targets provide cost-control but also limit market growth and reduce investment stability for market parties.

4.6. Simplify administrative procedures for small plants

In addition to lengthy administrative procedures the most important impact for the market is the pre-registration, a very long and bureaucratic process. Several alternatives exist to deal with administrative barriers, including simplifying procedures for small systems below 10 kW (even exempting them from getting permits) and establishing a one-stop-shop for all permitting procedures ([35]). However, pre-registration is a cost-containment mechanism. Its removal may not be attractive for governments concerned about cost-control.

It should be taken into account that a large number of small roof-top installations may lead to an excessive electricity generation at noon, overloading the distribution network. This may become an important issue if the policy encourages a lot of small installations and a significant generation of solar PV. Thus, the FIT should provide incentives to match consumption with generation and thus, minimise power flows (and losses) in the distribution network by, for example, encouraging the adoption of small, distributed storage systems (we thank an anonymous referee for this remark).

5. Conclusion

This paper has highlighted the important role of design elements within a FIT scheme in order to promote solar PV in an effective manner while tackling the concerns of policy makers about the high (and increasing) costs of support. Although empirical findings have shown that FITs are generally more effective and cost-efficient than alternative instruments and that they are also less risky for investors, the experience with solar PV in Spain (and other countries) shows that some design elements under FITs may lead to large cost increases, raising the concern of the government and triggering unexpected changes as a result. This creates policy instability and erodes investors' confidence, possibly leading to a boom-and-bust cycle. There might be a trade-off between providing favourable conditions for investors (low risk, high support levels) and having enough regulatory flexibility to control consumer costs. A greater risk for investors increases the risk premium for solar PV investments and, thus, induces a greater level of support. The challenge for policymakers is to achieve a balance between conflicting criteria by introducing appropriate design elements and in-built flexibility.

Dynamic in-built flexibility mechanisms should be included in FITs for solar PV in order to balance the security for investors with the control of overall support costs. Both aspects are related. If overall policy costs increase substantially, the social acceptability and political feasibility of support will decrease, leading to all sorts of cuts in support levels, generally for new plants but, if costs increase much, retroactive changes for existing plants may ultimately be in the agenda of policy-makers, as shown by the Spanish case. A reduction in policy feasibility is likely to increase policy instability, creating much uncertainty and risks for investors. In turn, higher investor risks would lead to higher risk premiums and to greater policy costs as investors require greater support levels. Thus, the challenge is to combine security for investors, which triggers investments and, thus, deployment, with support levels which are not excessive with respect to costs. Again, both aspects are not totally disconnected, since greater deployment everywhere contributes to advancements along the learning curve which, in turn, lead to cost-reductions and, thus, allow governments to apply lower support levels.

Different alternatives exist to achieve the aforementioned balance between apparently conflicting goals. Their choice depends on which are the priorities of governments. For example, frequent revisions (i.e., every three months as it is the case of flexible degression in Spain) would be attractive if the main goal is to control total costs, whereas revisions with longer periods (i.e., two years as in Germany) would be appropriate to ensure a continued flow of investments and deployment (i.e., lower risks for investors).

This paper suggests that some design elements are more appropriate than others in order to have an effective and cost-efficient promotion of solar PV. But all design elements have their pros and their cons. In particular, the implementation of cost-containment mechanisms in the form of flexible degression may address the usual problem when setting the level of support for FITs, which may either be set too high or too low. However, this system may also result in high administrative costs and uncertainty for investors. Anecdotal evidence suggests that the former are likely to be high, although there is no hard data on this, a usual problem with transaction and administrative costs of support schemes. Under this system, investors only have an approximate idea of what their revenue flows will be over time (since they will only know the support level once they are registered). Long-term targets mitigate this problem to some extent. Regarding the setting of binding or indicative targets, the choice depends on the priority of governments. Binding

targets address the cost issue but stifle investment. We strongly warn against announcing long in advance the end of the old regulation by a certain date and its replacement by a less attractive scheme, which likely lead to capacity booms.

Re-powering should be promoted in an appropriate manner (i.e., without providing the new modules the FIT level granted to the old ones). It is advisable to avoid retroactivity, since it is too drastic a way to control costs and it has short, medium and longer term consequences on market growth. Retroactive changes affect the credibility of support and constraints future investments. In turn, this increases the country risk-premium for investments in solar PV, making future deployment more costly (i.e., greater support levels). Changes to the policy framework over time should be gradual and predictable. Therefore, regulations should include flexible and adaptable revision mechanisms in order to avoid boom phenomena as it occurred in Spain.

The Spanish case further suggests a more general conclusion: the choice of design elements leads to a convergence of RES-E schemes regarding PV support. The Spanish flexible degression and quota (*cupo*) scheme has some elements of a quota system (annual caps) and could evolve into a tendering scheme in the future. In fact, some design elements (such as those adopted to control for both quantity and costs) may blur the traditional distinction between quantity-based (i.e., quota with tradable green certificates and tendering schemes) and price-based schemes (FITs), suggesting that schemes may converge when deployment increases significantly, the costs of support become a major concern and governments implement design elements to address this problem.

Several issues are worth exploring in further research. First, the appropriate combination of support for deployment and support for research and development regarding solar PV should be analysed. No explicit coupling of both types of support has taken place in Spain. Second, the role of tendering/bidding schemes for solar PV promotion should be studied, given its combination of a capacity cap, incentives for cost reductions, price transparency and high security for investors (once bids are awarded). Experience with this instrument in the past suggests that it may be particularly suitable for large projects and less so for small actors ([38]). There are recent experiences with tendering schemes for solar PV deployment in India, China, Chile and France, but they are too recent to derive conclusions about their functioning. Therefore, their role in supporting solar PV has to be taken with caution. And, finally, it should be explored the combination of a FIT with other support schemes such as investment subsidies and soft loans.

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